THE BENEFITS OF DYEING
COTTON WITH DIRECT DYES

by

Michel A. Herlant
Technical Director
Crompton & Knowles Corporation

COTTECH CONFERENCE 1991
Cotton Incorporated
Raleigh Marriott Crabtree Valley
November 14-15, 1991
THE BENEFITS OF DYEING COTTON WITH DIRECT DYES

Michel A. Herlant & Steven R. McDaniel
Crompton & Knowles Corporation

To be competitive in today's market, it is essential for the dyehouse superintendent to optimize the selection process when deciding which class of dye to use when dyeing 100% cotton or cotton blends.

In addition to direct dyes, there is a wide choice of about half a dozen types of fiber reactive dyes - all having different reactive groups. Where the highest possible fastness are required, vat dyes still represent the answer. Sulfur dyes also still have a place, especially in continuous dyeing, as well as in Jig dyeing of heavy shades. Pigments in exhaust application are another possibility, primarily in garment dyeing; however, these dyes have limited fastness. In general, however, the majority of cotton dyeings is made either with fiber reactives or direct dyes.

In reviewing the benefits of direct dyes when dyeing cotton, we will do so in comparison with reactive dyes.

The purpose of this article is to demonstrate that reactive dyes do not have to be used across the whole color spectrum to dye cotton. We will illustrate the many areas where directs should be used because of their attractive properties. Our intentions are certainly not to discredit the technical merits of fiber reactive dyes, because there is most definitely a need to use fiber reactive dyes. For example, where the fastness requirements are set high, where the depth of shade and the shade itself make the use of direct dyes totally unacceptable.

There are, however, many good reasons why direct dyes are often the preferred choice.

Direct dyes are preferred for their:

1. Lower cost of dyeing resulting from lower dye and chemical cost, lower water consumption, shorter dyeing times. Total dye costs are on average about 30-40% lower for direct dyes. This cost comparison is not always true when dyeing blacks. (See attached diagrams illustrating a fiber reactive complete dye cycle with rinses and hot scour for a hot dyeing fiber reactive dye (mono-chlorotriazine) or vinyl sulfone fiber reactive dye and a direct dyeing.

2. Direct dyes are easy to apply with proper training and they can be used in almost any dyehouse equipment by exhaust or continuous. Direct dyes offer a predictable shade build-up and good repeatability from lot to lot.

3. Direct dyes are environmentally less questionable than fiber reactive dyes, since much lower concentrations of Glauber's salt
or common salt are required to achieve a very high degree of dye exhaustion. Fiber reactive dyes require amounts often five to ten times higher. With a selection of B-type direct dyes, it is indeed possible to exhaust as much as 95% or higher of the dye on the cotton fiber, compared with only 65-75% for most fiber reactive dyes. (1)

Attached are direct dyeings illustrated in increasing depths of shade obtained with low amounts of salt, as well as charts where the % dye exhausted is plotted out. Among the blue direct dyes illustrated are dyes which contain one molecule of copper per molecule of dye. The very high degree of exhaustion inhibits significantly the discharge of copper in the effluent. Most fiber reactive dyes require very high salt concentrations from 30 to at least 80 grams/liter to achieve their maximum degree of exhaustion and fixation on the fiber. Even after applying the dyes under optimum conditions, it is common to discharge as much as 20 to 30% of the dye. Attached is slide illustrating the need to increase the salt concentration in order to achieve adequate reactive dye exhaustion and fixation.

4. Direct dyes are less affected by variations in liquor ratio than fiber reactive dyes. Illustrated is chart with depth of shade being directly affected when dyeing with fiber reactive dyes at a different liquor ratio. Only certain multi-anchored fiber reactive dyes with higher substantivity for cotton demonstrate less liquor ratio dependency, as well as requiring less salt to achieve high exhaustion.

5. When dyeing cotton/polyester blends the most efficient way is to use a selection of high temperature stable direct dyes and the appropriate disperse dyes. Both classes of dyes are compatible with one another at the acid pH of 5.0 - 6.0, and therefore, can be applied by the one-bath/two-step high temperature dyeing procedure. There is a wide selection of direct dyes which are stable to the H.T. conditions of up to (130°C/265°F).

Fiber reactive dyes require alkaline conditions and fairly high salt concentrations. Obviously, these are conditions to which most commercial disperse dyes are not compatible with. Attached are dyeing diagrams illustrating comparatively dye cycles of disperse/directs versus disperse/reactives.

6. A majority of direct dye shades, from light and medium to medium dark depths, aftertreated with a direct dye fixative have wetfastness acceptable to apparel requirements.

ASTM Standard Performance Specification Requirements:
1. Women's and girls' woven sportswear, shorts, slacks and suit ing fabrics.
2. Men's and boys'knitted dress suit fabrics and knitted sportswear jackets, slacks and trouser fabrics.
Laundering:
Shade change- Class 4 minimum (AATCC Gray Scale for color change)
Staining- Class 3 minimum (AATCC Gray Scale for staining)

Over the years, it has been customary for dyestuff manufacturers to test wetfastness of dyeings with recommended AATCC or ISO specifications. Direct dye shade cards issued by dyestuff manufacturers have always given fastness ratings for dyeings performed at a 1:1 standard depth; except for navies and blacks which are tested in the depth at which they are illustrated. An exception was made early on when dealing with the lightfastness tests which are usually performed on different depths. There is some good reason for this, since the fastness ratings vary according to the depth of the shade. Lighter depths usually results in lower fastness ratings.

Likewise, however, the reverse can be said about a 2A wash test performed on dyeings obtained with direct dyes. This is significant for many direct dyes since they demonstrate higher and quite acceptable fastness ratings when aftertreated with a direct dye fixative. When relying exclusively on the 2A wash fastness ratings of direct dye shade cards, one may be eliminating a dye which may give acceptable fastness rating at a slightly lower depth of shade.

The attached fastness ratings illustrate wash test results obtained of direct dyeings performed on cotton at light to medium depths. There is one direct dye which gives good wetfastness results even as a black - C.I. Direct Black 22, when aftertreated with the appropriate direct dye fixative.

One negative point about direct dye fixatives is that they may cause an undesirable alteration of the shade dyed, as well as reduce its lightfastness. However, the resulting lightfastness is usually acceptable for the apparel end-use. Quite many direct dyes are bright; actually, some of these are as bright as reactive dyes. However, when dyeing dark bright shades, it is suggested to dye with fiber reactive dyes in order to obtain acceptable washfastness.

7. A selection of direct dyes have good lightfastness when dyed on bleached cotton. Because of this advantage, directs are used when dyeing home furnishings. Use of a direct fixative is not suggested since the lightfastness is adversely affected. However, use of an anti-migrant is recommended after dyeing.

8. A wide selection of directs are preferred for their good nylon reserving properties when dyeing blends of cotton/nylon fabrics from a one-bath dyeing system. (exhaust and continuous)

9. In addition to batch or exhaust dyeing application methods, properly selected direct dyes can be used to dye cotton continuously. Preferred are highly concentrated dyes for optimum solubility and no tailing. Some of the dyes are in a 200 to 300% form or two to three times more concentrated than the standard form offered to exhaust dyehouses. Highly concentrated dyes can be
applied basically by three continuous and semi-continuous dyeing methods:

1) **Pad-Steam**

100% cotton fabrics or cotton blended with nylon or acrylic fibers can be dyed continuously on specially developed dyeing equipment (Kuesters®). A vast experience has been accumulated over the years in processing velours and upholstery fabrics using a spiral steamer. Nylon/cotton fabrics for automotive bodycloth use are still today dyed successfully with direct and neutral premetalized dyes by the pad-steam method.

2) **Cold Pad-Batch**

A selection of highly concentrated direct dyes offers the pad-batch dyer the possibility to dye cotton fabrics by the cold pad-batch method. One of the main attractions of this application is the absence of large quantities of alkali (sodium silicate and caustic soda) normally required when pad-batch dyeing fiber reactives. Fairly medium-dark shades can be obtained during overnight batching 15-18 hours. With properly selected highly concentrated dyes, it is possible to achieve good depths of shade with minimal amount of wash-down. Following a few rinses, one gives a final cold rinse in a wash-box containing 20-30 g/l of a direct dye fixative. Further development work will be performed to expand the list of appropriate direct dyes. Initial results obtained are very encouraging.

3) **Pad-Dry**

This method is not new and it has been used to dye light-to-medium depths of shade. Properly prepared goods (boiled and bleached demonstrating a high degree of wetting ability can be dyed continuously with a kiss-roll applicator and dried. The dye solution is hot (75-80°C) and can contain a small amount of salt as migration inhibitor during drying, if necessary. **Note:** In order to avoid "tailing" in continuous dyeing of direct dyes, it is important to minimize the immersion time of the fabric in the padding solution. This can be accomplished directly through controlling the volume of the trough and padding speed.
CONCLUSION:

- This quick review of advantages offered by the use of direct dyes should encourage anyone to seriously consider direct dyes.

- There is no doubt that direct dyes needing less salt than fiber reactives is an advantage to the dyer who may have to curtail the use of fiber reactive dyes in order to stay within the approved limits of salt being discharged.

- Quite many direct dyes possess adequate wetfastness when dyed at depths less than 1:1 standard depth.

- Highly concentrated dyes with good solubility allow for continuous dyeing of 100% cotton and cotton blended fabrics by different techniques.

References: (1) "Low Salt Dyeing With Directs and Fiber Reactives"
M. Herlant - AATCC 1991 Convention - Charlotte, NC
2A Wash Test Results of Direct Dyeings on Cotton Knit

![Graph showing wash test results of direct dyeings on cotton knit. The graph plots AATCC Stain Scale against Dye O.W.F. in Dyebath. Lines represent different dye combinations: Intralite Blue NBLL and Intralite Blue FGL, Superliterate Yellow EFC, Superliterate Orange EGLL and Intralite Scarlet BNLL, Direct Brilliant Pink B.]}
Direct Brilliant Pink B
Superlightfast Orange ECL
Interactive Scarlet ELL
Interactive Blue ECL
Superlightfast Yellow EFC and Interactive Blue ELL

Dye O.W.F. in Dyebath

AATCC ALTERATION SCALE

Direct Dyesings on Cotton Knit

2A Wash Test Results of
VINYL SULFONE REACTIVE (ALL-IN METHOD)

1. Calgon/Salt
2. Dissolved Dye
3. Alkali

1. Cold Wash
2. Acidify
3. Hot Wash
4. Soap Wash

Temperature:
- 90°F
- 140°F
- 160°F
- 200°F

Time:
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9

Hours:
DISPERSERS VS REACTORS - 2 BAY - DISPERSER WE FIRST
1. Calgon/Salt
   10 mins.
2. Dissolved Dye
   20 mins.
3. Alkali
   20 mins.
4. Cold Rinse
5. Disperse Dyebath Chemicals
6. Dispersed Dye
7. Intraquest B
8. Rinse
EPA Limits On Salt In Effluent

<table>
<thead>
<tr>
<th>LC 50</th>
<th>2000 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio Assay Cerio Daphne</td>
<td>or 0.2% = 2 grams/liter</td>
</tr>
</tbody>
</table>
Amount of Salt Generally Used With Direct and Reactive Dyes

<table>
<thead>
<tr>
<th>Depth of Shade</th>
<th>Direct</th>
<th>Reactive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pastel/Light up to 0.5% – 1.5%</td>
<td>2.5 – 7.5 g/l</td>
<td>30 – 60 g/l</td>
</tr>
<tr>
<td>Medium 1.0% – 2.5%</td>
<td>7.5 – 12.5 g/l</td>
<td>60 – 80 g/l</td>
</tr>
<tr>
<td>Dark above 2.5%</td>
<td>12.5 – 20 g/l</td>
<td>80 – 100 g/l</td>
</tr>
</tbody>
</table>
## Direct Dyes

<table>
<thead>
<tr>
<th>Dyes Evaluated</th>
<th>SDC Classification</th>
<th>C.I. Direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intralite Yellow 2RLSW</td>
<td>A</td>
<td>Yellow ---</td>
</tr>
<tr>
<td>Superlitefast Yellow EFC</td>
<td>B</td>
<td>Yellow 106</td>
</tr>
<tr>
<td>Superlitefast Orange EGLL</td>
<td>B</td>
<td>Orange 39</td>
</tr>
<tr>
<td>Intralite Scarlet BNLL</td>
<td>B</td>
<td>Red 89</td>
</tr>
<tr>
<td>Intralite Brilliant Scarlet 2GL</td>
<td>B</td>
<td>Red 224</td>
</tr>
<tr>
<td>Intralite Red 2HT New</td>
<td>B</td>
<td>Red 243</td>
</tr>
<tr>
<td>Sol-Aqua-Fast Red 2BL</td>
<td>B</td>
<td>Red 80</td>
</tr>
<tr>
<td>Direct Brilliant Pink B</td>
<td>A</td>
<td>Red 9</td>
</tr>
<tr>
<td>Intralite Blue FGL</td>
<td>B</td>
<td>Blue 90</td>
</tr>
<tr>
<td>Intralite Blue NBLL</td>
<td>B</td>
<td>Blue 80(s)</td>
</tr>
<tr>
<td>Intralite Brilliant Blue L</td>
<td>B</td>
<td>Blue 98(s)</td>
</tr>
<tr>
<td>Superlitefast Blue RL</td>
<td>B</td>
<td>Blue 80</td>
</tr>
</tbody>
</table>
Intralite Yellow 2RLSW
C.I. Yellow ---

Influence of Glauber's Salt on Dye Exhaustion
Influence of Glucobers Salt on Dye Exhaustion

DYE O.W.F IN DYE BATH

%0
%10
%20
%30
%40
%50
%60
%70
%80
%90
%100

DYE EXHAUSTION COTTON

C.I. Direct Yellow 106
Superfast Yellow EFC
Superlitefast Orange EGLL
C.I. Direct Orange 39

Influence of Glauber’s Salt on Dye Exhaustion
Intralite Brilliant Scarlet 2GL
C.I. Direct Red 224

Influence of Glauber's Salt on Dye Exhaustion
Intralite Scarlet BNLL
C.I. Direct Red 89

Influence of Glauber's Salt on Dye Exhaustion
Intralite Red 2HT New
C.I. Direct Red 243:1

Influence of Glauber's Salt on Dye Exhaustion
Influence of Gluabers Salt on Dye Exhaustion

C.I. Direct Red 9

Direct Brilliant Pink B
Influence of Gluabers Salt on Dye Exhaustion

Dye Exh. On Cotton

C.I. Direct Blue 80
Superlutefast Blue Rl
Intralite Fast Blue FGL
C.I. Direct Blue 90

Influence of Glauber's Salt on Dye Exhaustion
Intralite Blue NBLL
C.I. Direct Blue 80(s)

Influence of Glauber's Salt on Dye Exhaustion
Intralite Brilliant Blue L
C.I. Direct Blue 98(s)

Influence of Glauber's Salt on Dye Exhaustion
Influence of Salt Concentration on Dye Yield of Vinyl Sulfone Fiber Reactive Dyes

2% Dye: LR 20:1 @ 60° C, 10 g/l TSP

- C.I. Reactive Yellow 15
- C.I. Reactive Yellow 17
- C.I. Reactive Orange 16
- C.I. Reactive Red 49
Influence of Salt Concentration on Dye Yield of Multi-Anchored Fiber Reactive Dyes

2% Dye: LR 20:1 @ 60° C, 10 g/l TSP

- C.I. Reactive Yellow
- C.I. Reactive Orange
- C.I. Reactive Red 195
- C.I. Reactive Blue 221

Graph showing maximum yield against common salt concentration (20 g/l to 80 g/l).
Influence of Salt Concentration on Dye Yield of Vinyl Sulfone Fiber Reactive Dyes

2% Dye: LR 20:1 @ 60° C, 10 g/l TSP

C.I. Reactive Yellow 15
C.I. Reactive Yellow 17
C.I. Reactive Orange 16
C.I. Reactive Red 49
Influence of Salt Concentration on Dye Yield of Multi-Anchored Fiber Reactive Dyes

2% Dye: LR 20:1 @ 60° C, 10 g/l TSP

- C.I. Reactive Yellow
- C.I. Reactive Orange
- C.I. Reactive Red 195
- C.I. Reactive Blue 221

Graph showing the maximum yield vs. common salt concentration.